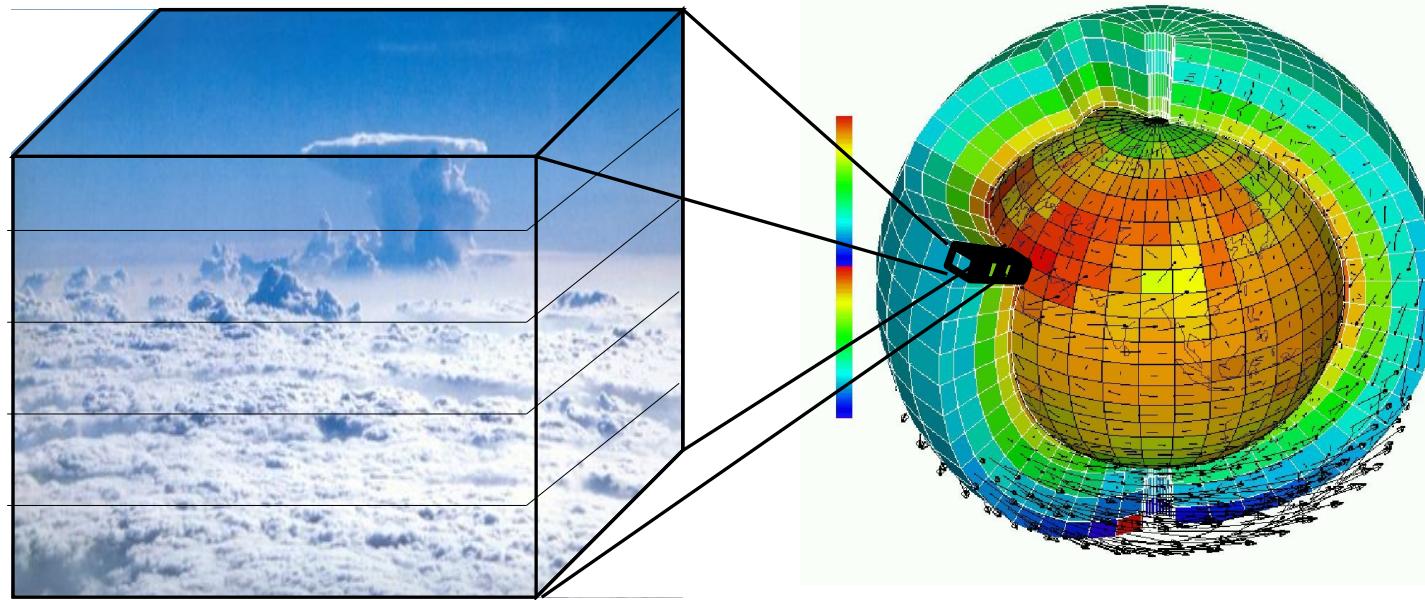


Evaluation of the diurnal cycle of continental deep convection in a large-scale model using AMMA observations

Catherine Rio (1)

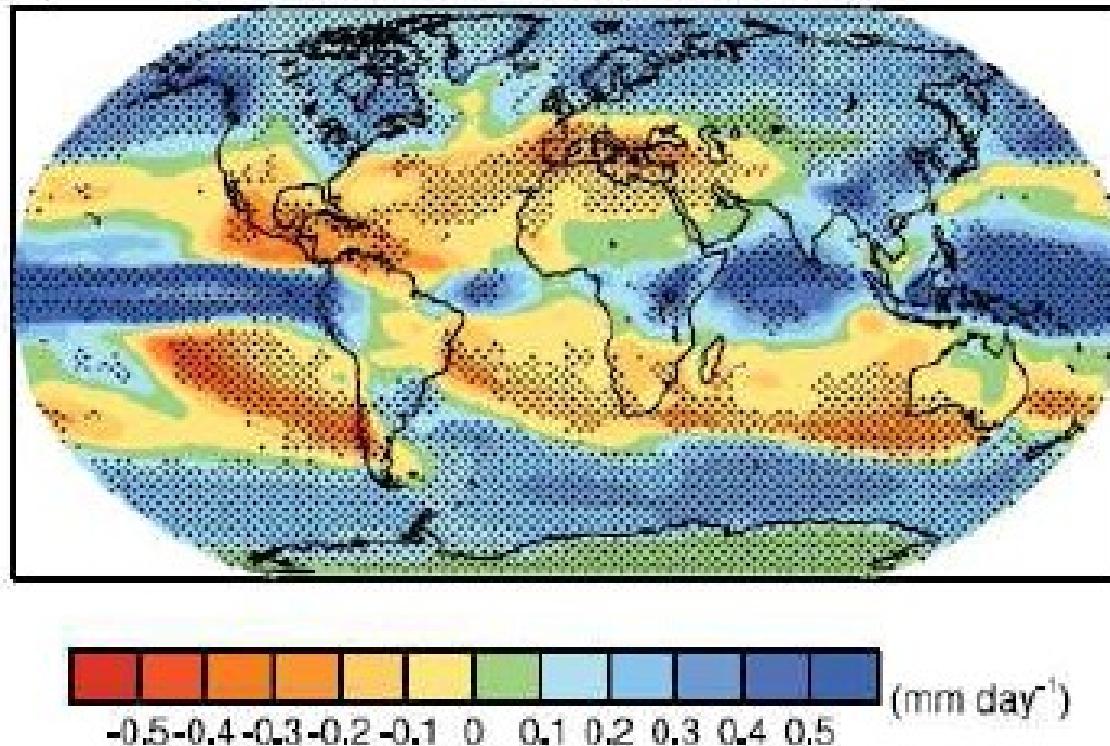
Frédéric Hourdin (2), Fleur Couvreux (1), Jean-Yves Grandpeix (2),
Françoise Guichard (1), Jean-Philippe Lafore (1), Marie Lothon (3),
Bernard Campistron (3), Michel Chong (3), Dominique Bouniol (1)



- (1) Météo-France/CNRS, CNRM/GMME/MOANA, Toulouse, France
(2) Laboratoire de Météorologie Dynamique, IPSL/CNRS, Paris, France
(3) Laboratoire d'Aérologie, CNRS, Toulouse/Lannemezan, France

How to improve climate change projection reliability?

Uncertainties in the evolution of precipitation:



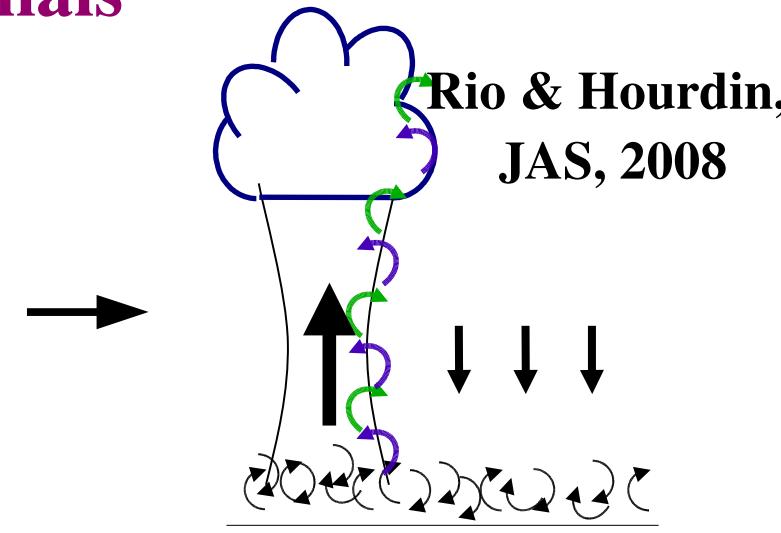
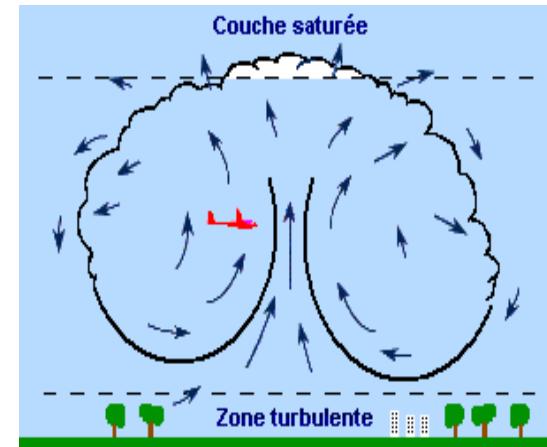
A need to improve the representation of physical processes related to convection and clouds in climate models

boundary layer
coherent structures
and clouds

deep convection

cold pools

Boundary layer thermals



Eddy-diffusivity / mass-flux approach for the convective boundary layer

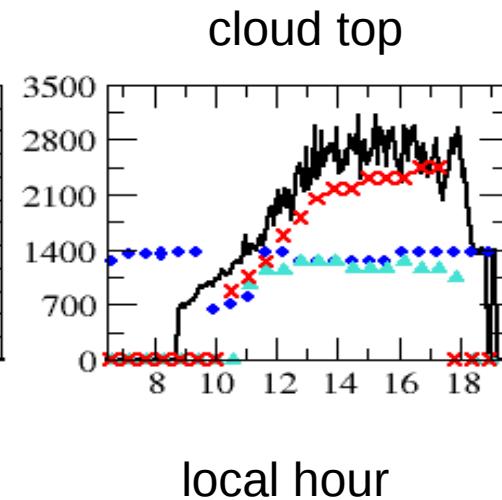
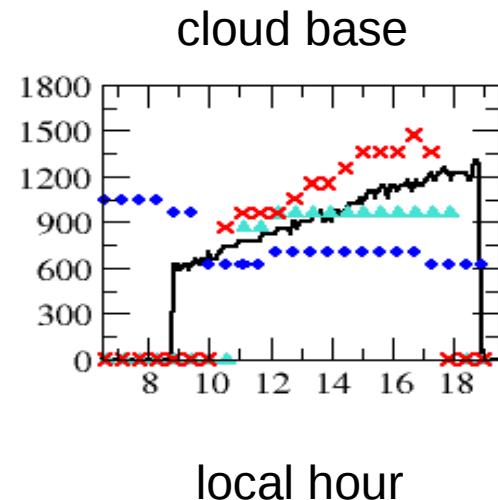
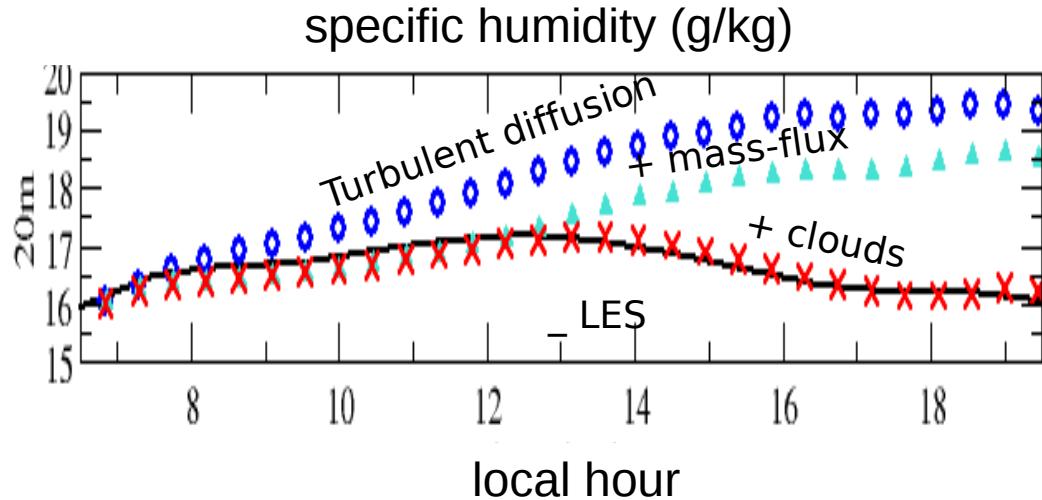
(Soares & al., 2004, Siebesma & al., 2007, Neggers & al., 2009)

Diurnal cycle of cumulus over land (GCSS SGP ARM case)

$$\rho \overline{w' \theta} = -\rho K \frac{\partial \theta}{\partial z} + f(\theta_a - \theta)$$

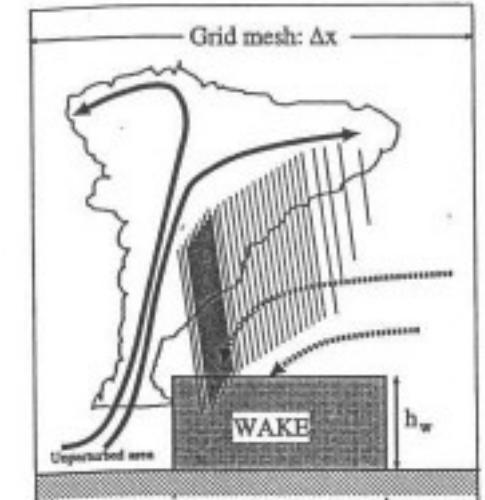
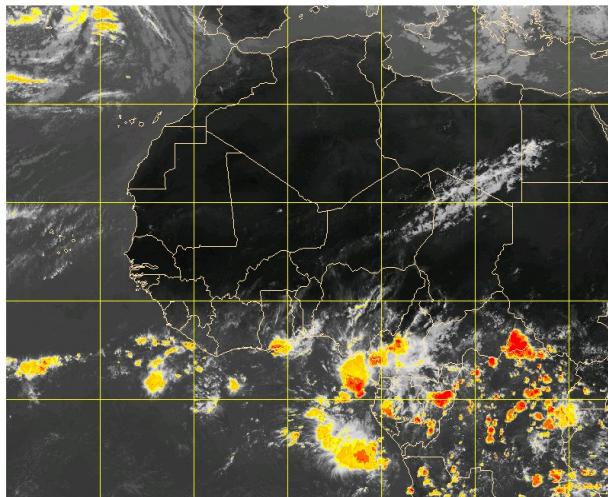
α $1-\alpha$

diffusive mass-flux
TKE approach



Cold pools

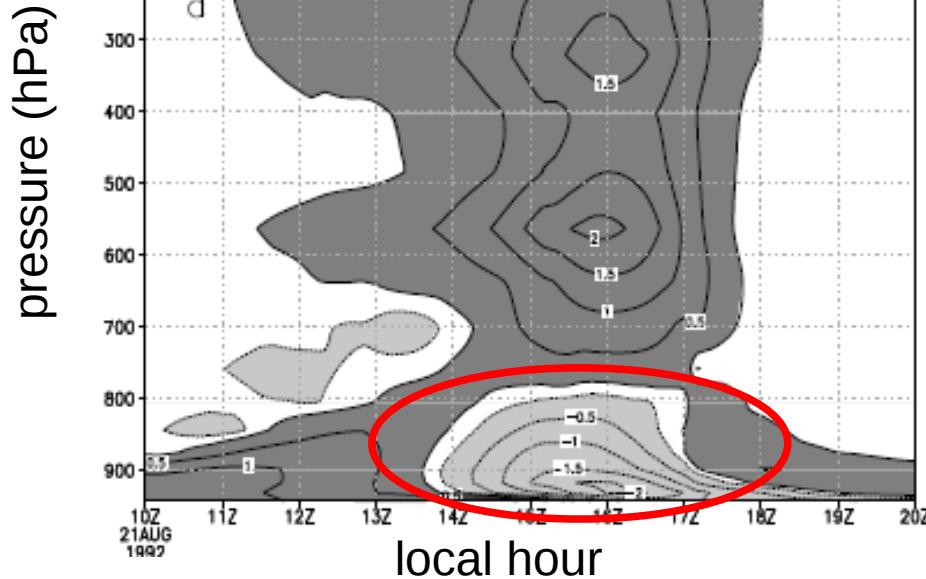
Parameterization of cold pools
Grandpeix & Lafore, JAS, 2009



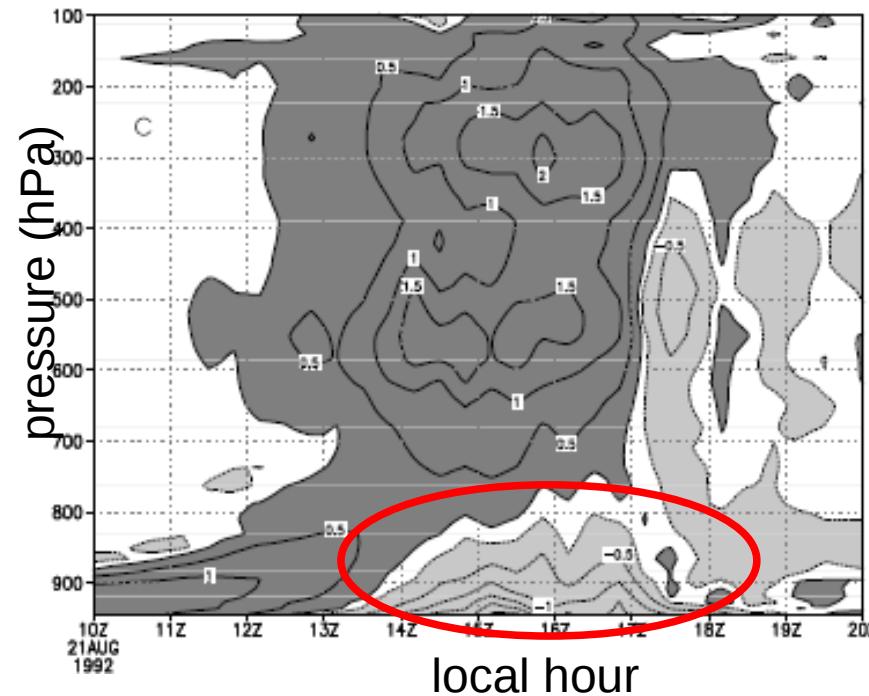
Picture by Guichard Fran  oise

Gust front propagation (HAPEX Sahel case)

LMDZ (SCM)



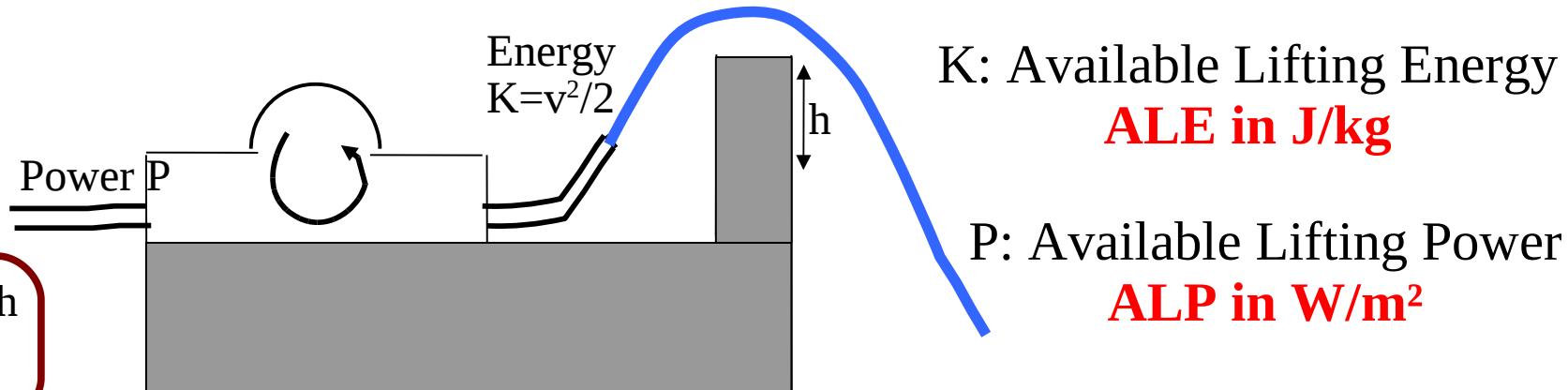
MESO-NH (CRM)



heating
rate
(K/h)

Deep convection

derived from Emanuel (1991): Grandpeix & Lafore, JAS, 2009

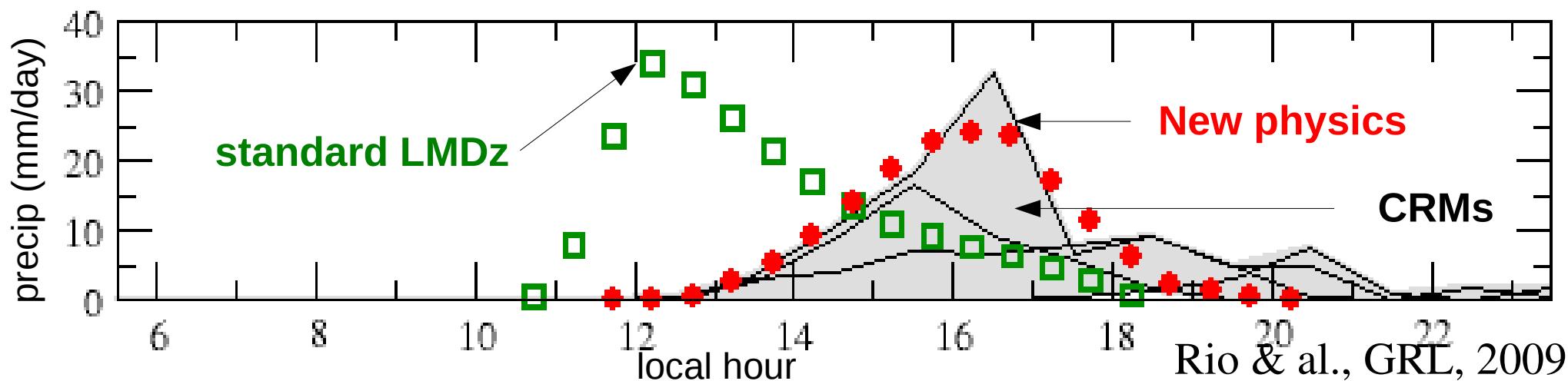


How deep convection is controlled by thermals and cold pools:

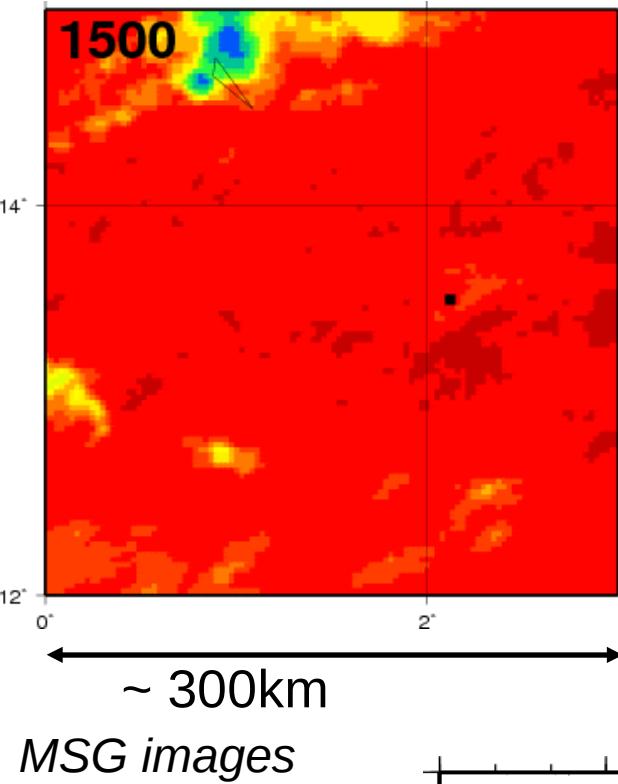
➤ Deep convection triggering:
 $\text{MAX}(\text{ALE}_{\text{th}}, \text{ALE}_{\text{cp}}) > |\text{CIN}|$

➤ Deep convection intensity:
Mass flux = $F(\text{ALP}_{\text{th}} + \text{ALP}_{\text{cp}})$

Diurnal cycle of deep convection on 27 June 1997 in Oklahoma (EUROCS case)



The 10th of July 2006 over Niamey

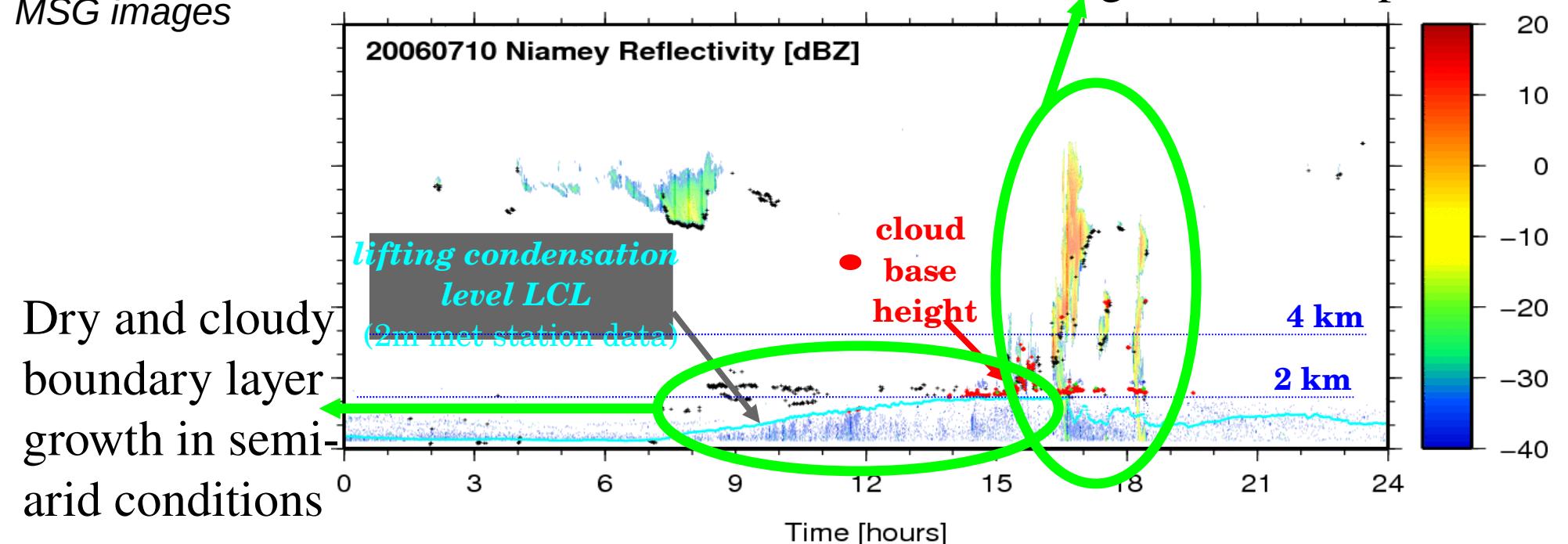


Local deep convection initiates over Niamey during the afternoon

Available observations:

- Instruments of the ARM Mobile Facility
- MIT RADAR
- Soundings above Niamey
- ATR flight
- AMMA CATCH surface fluxes data
- Satellite imagery

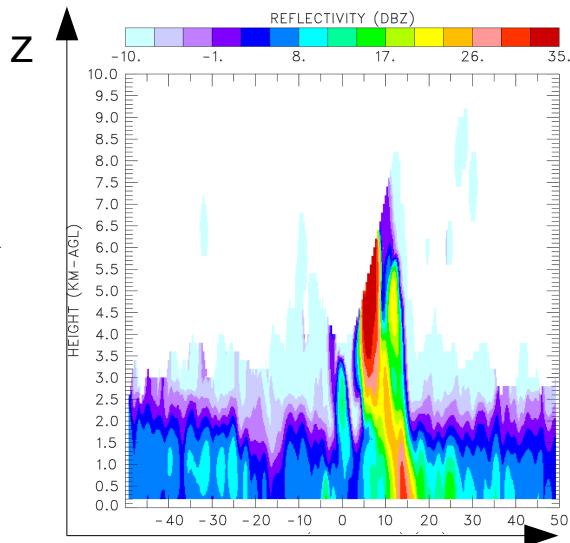
Transition from shallow to deep convection / growth of deep convection



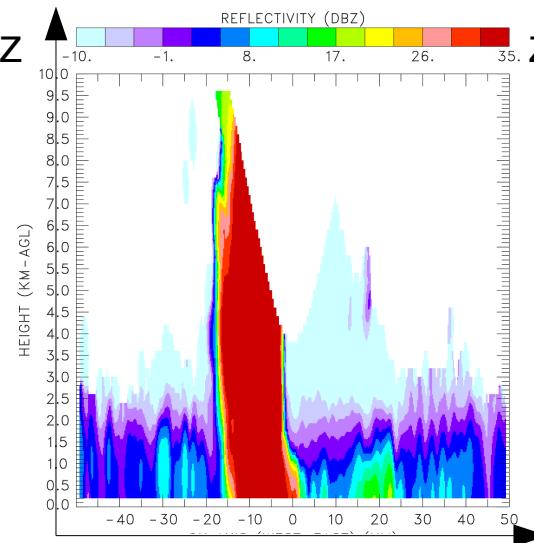
The 10th of July over Niamey

The convective cell developed in the MIT radar vicinity...

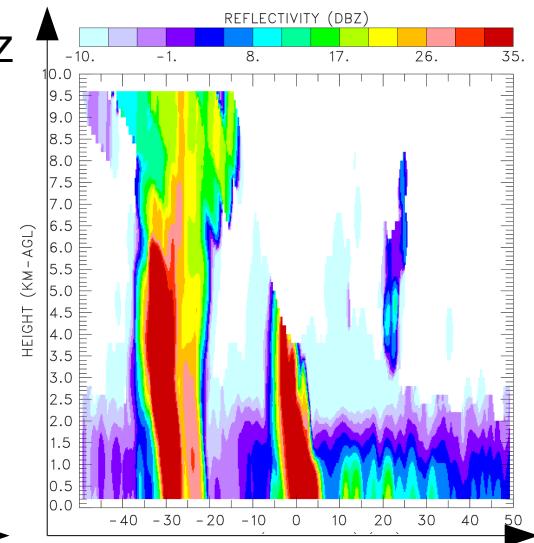
Vertical
cross-section
of reflectivity
5km to the
north



16h01 UTC X

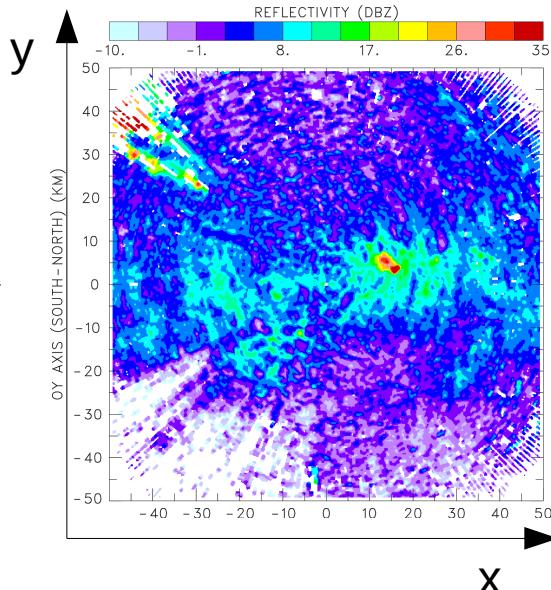


16h41 UTC X

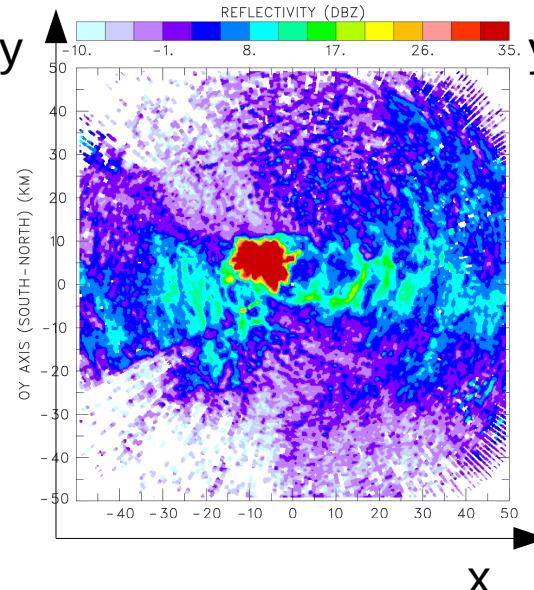


17h21 UTC X

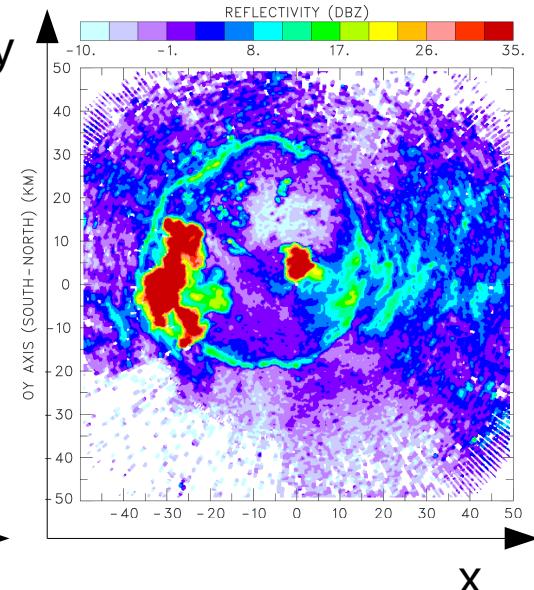
Horizontal
cross-section
of reflectivity
at 600m
height



X



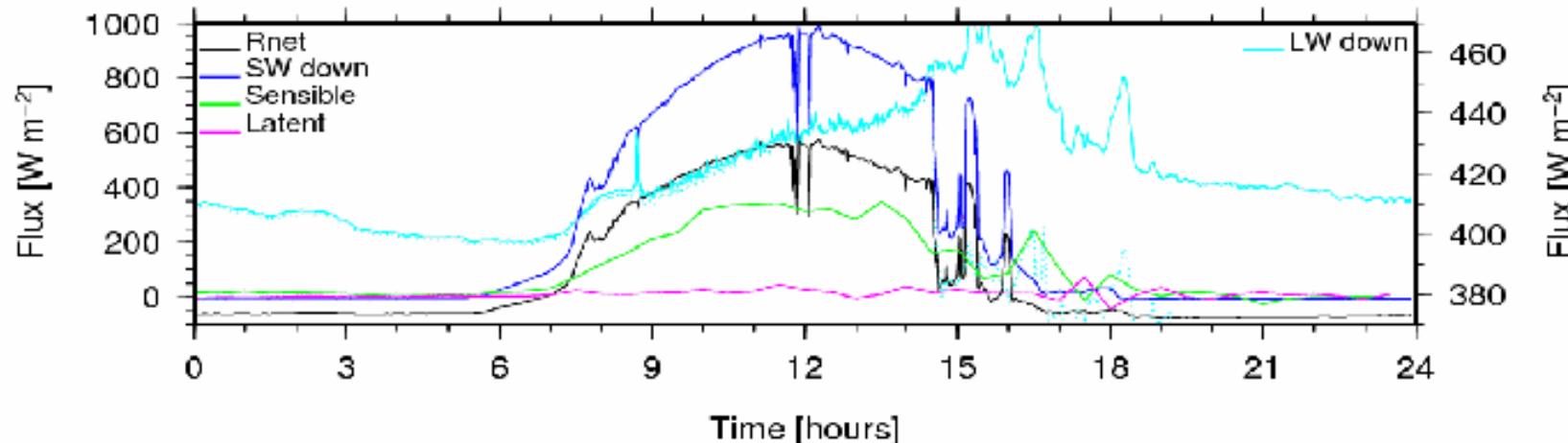
X



X

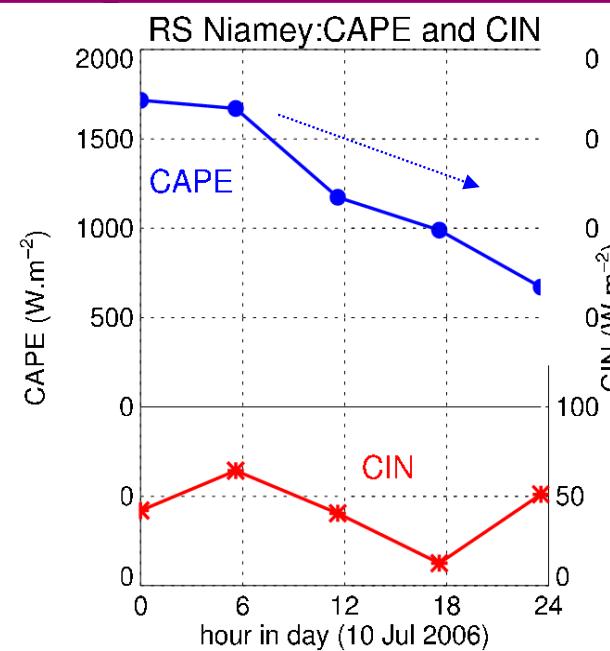
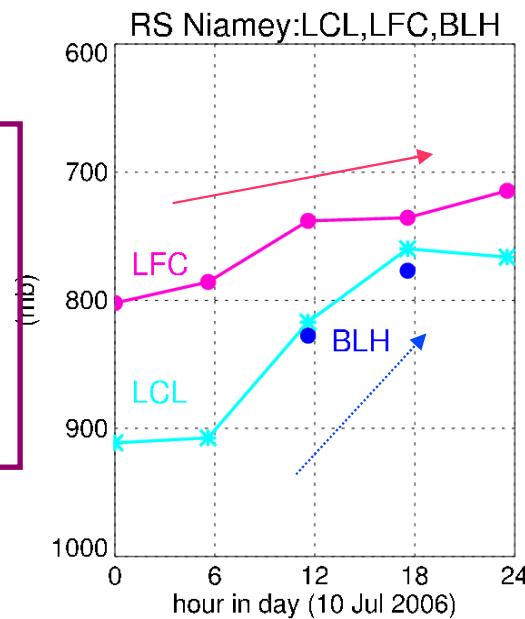
The 10th of July over Niamey

A fairly common situation in this region but rather different from other regimes studied so far, like convection over Amazonia or over the Great Plains



Almost no surface evapotranspiration ($\text{Bo}=\text{H}/\text{LE} \sim 10$)

Relatively high cloud base $\sim 2 \text{ km}$



CAPE decreasing
CIN minimal
at 18LT

Semi-arid conditions

Cloud Resolving Modelling

MESO-NH 3D Model

Domain size: 100km x 100km

Resolution: 500m

12 hours of simulation from 6am

Parameterizations:

3D turbulence (Deardorff length scale)
microphysics (liquid, ice, rain, graupel)

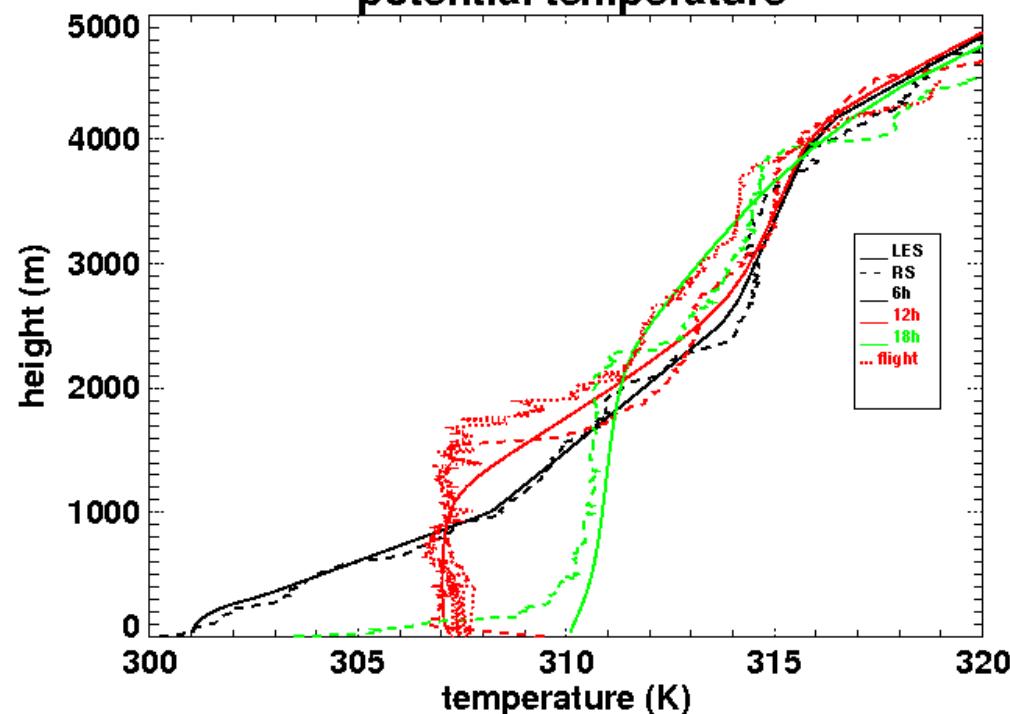
Vertical profiles of temperature and humidity

6h

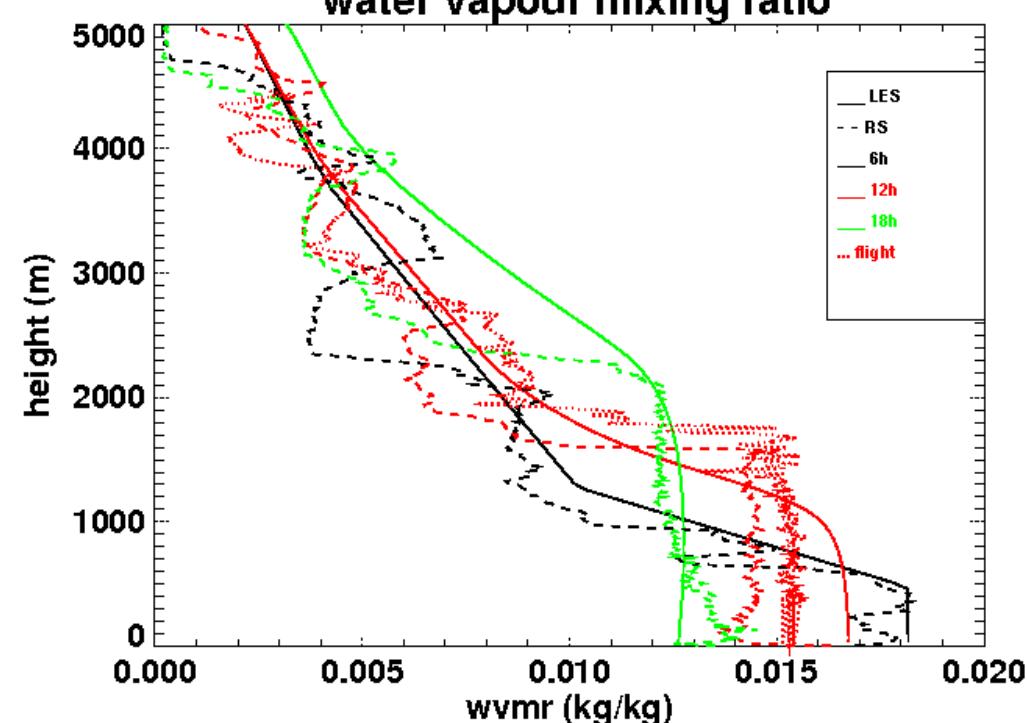
12h

18h

potential temperature



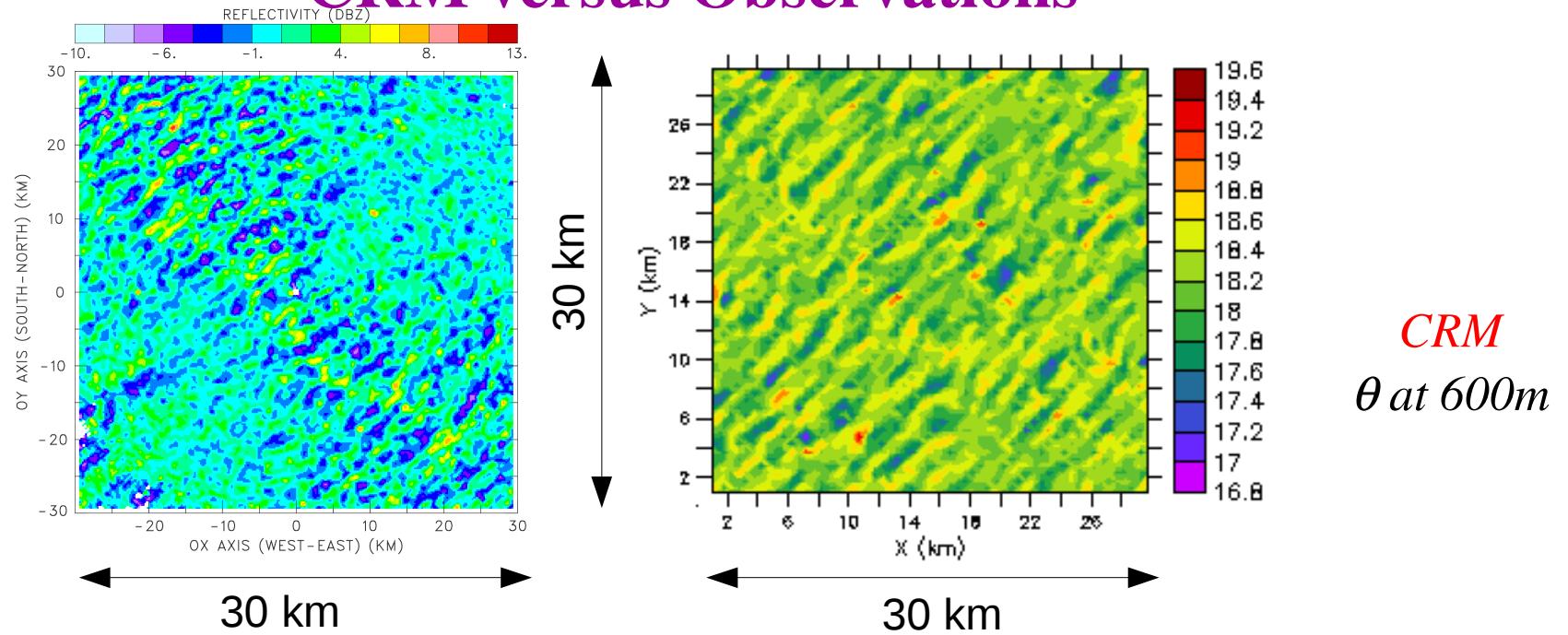
water vapour mixing ratio



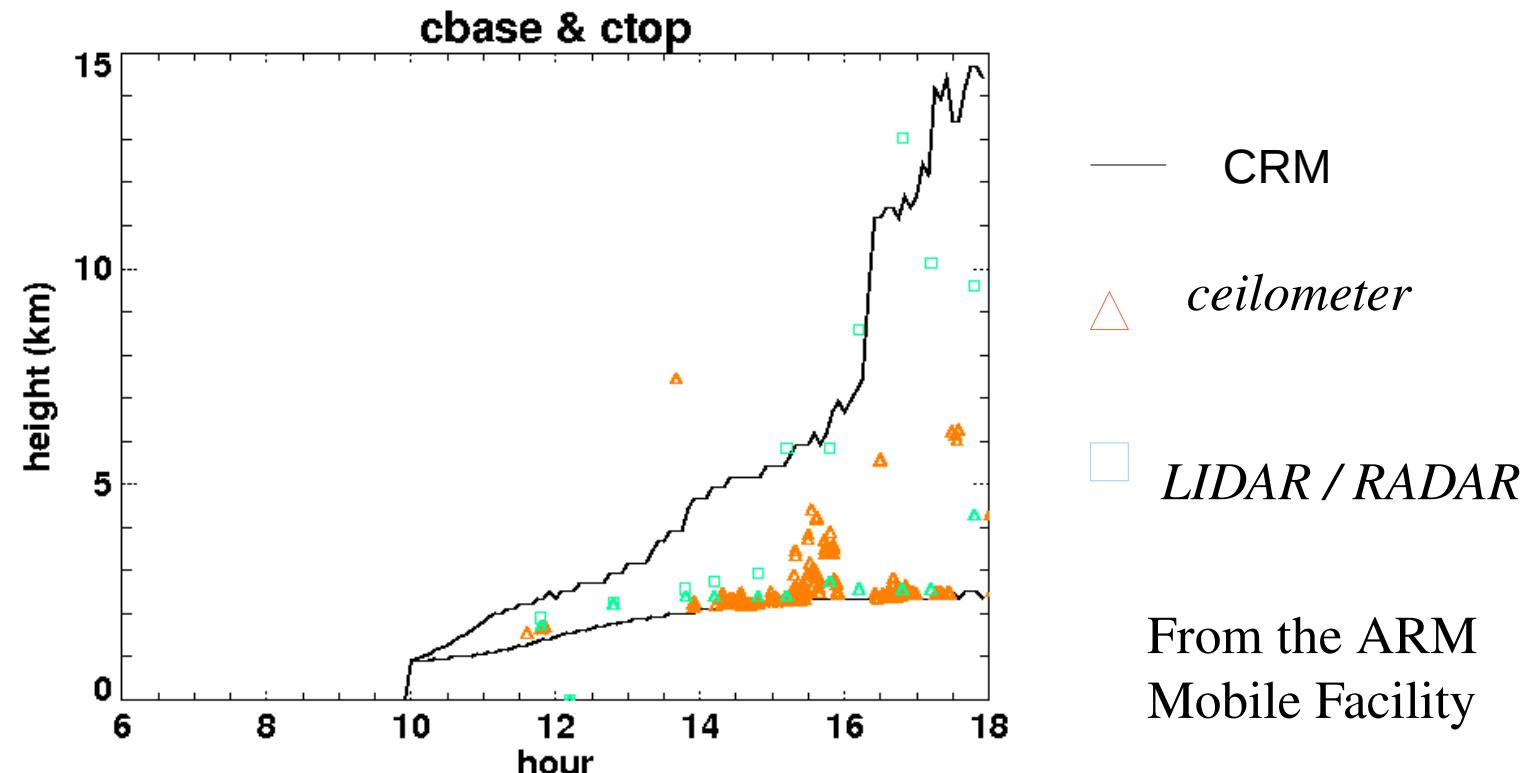
CRM versus Observations

Boundary layer structures in the morning

*MIT RADAR
reflectivity
at 600m*

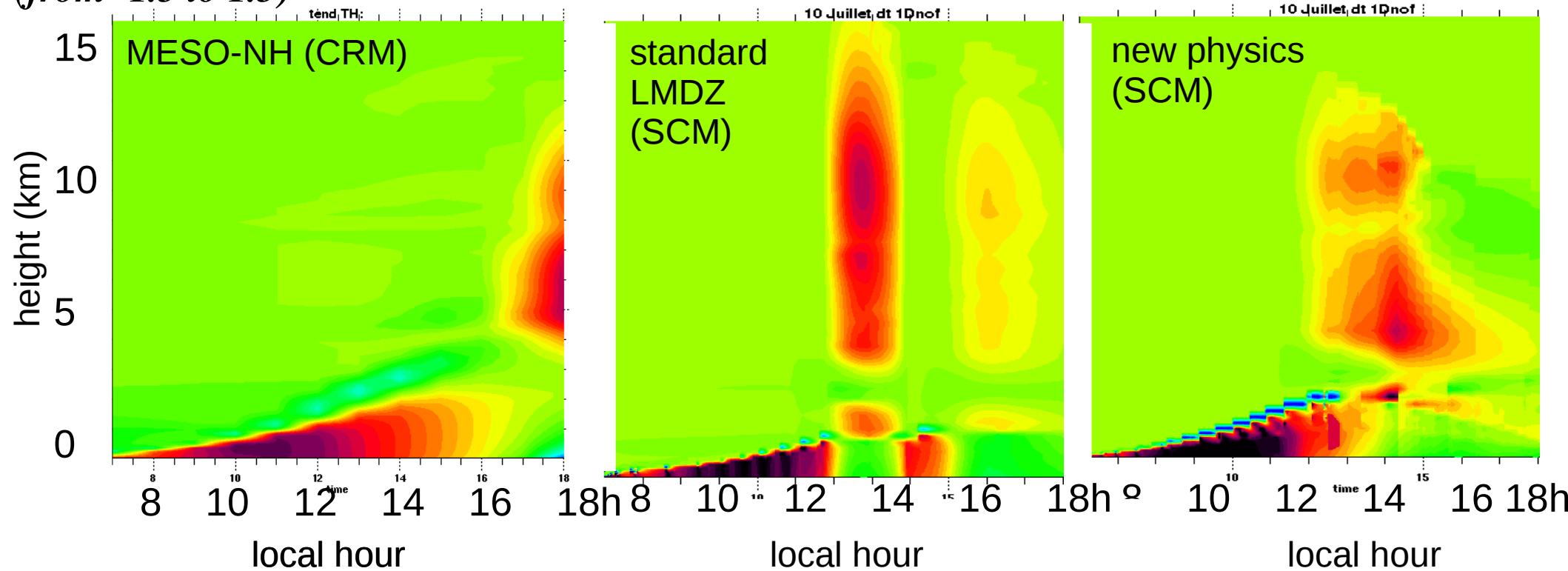


*Development of shallow
and deep clouds
during the day*



*Heating rate K/h
(from -1.5 to 1.5)*

CRM versus 1D simulations



Improvement of:

- boundary layer development
- deep convection sustainment

But:

triggering of deep convection still 3 hours too early

What key factor is still missing: structures size? tropospheric humidity?
specification of mixing rates?...

Conclusions

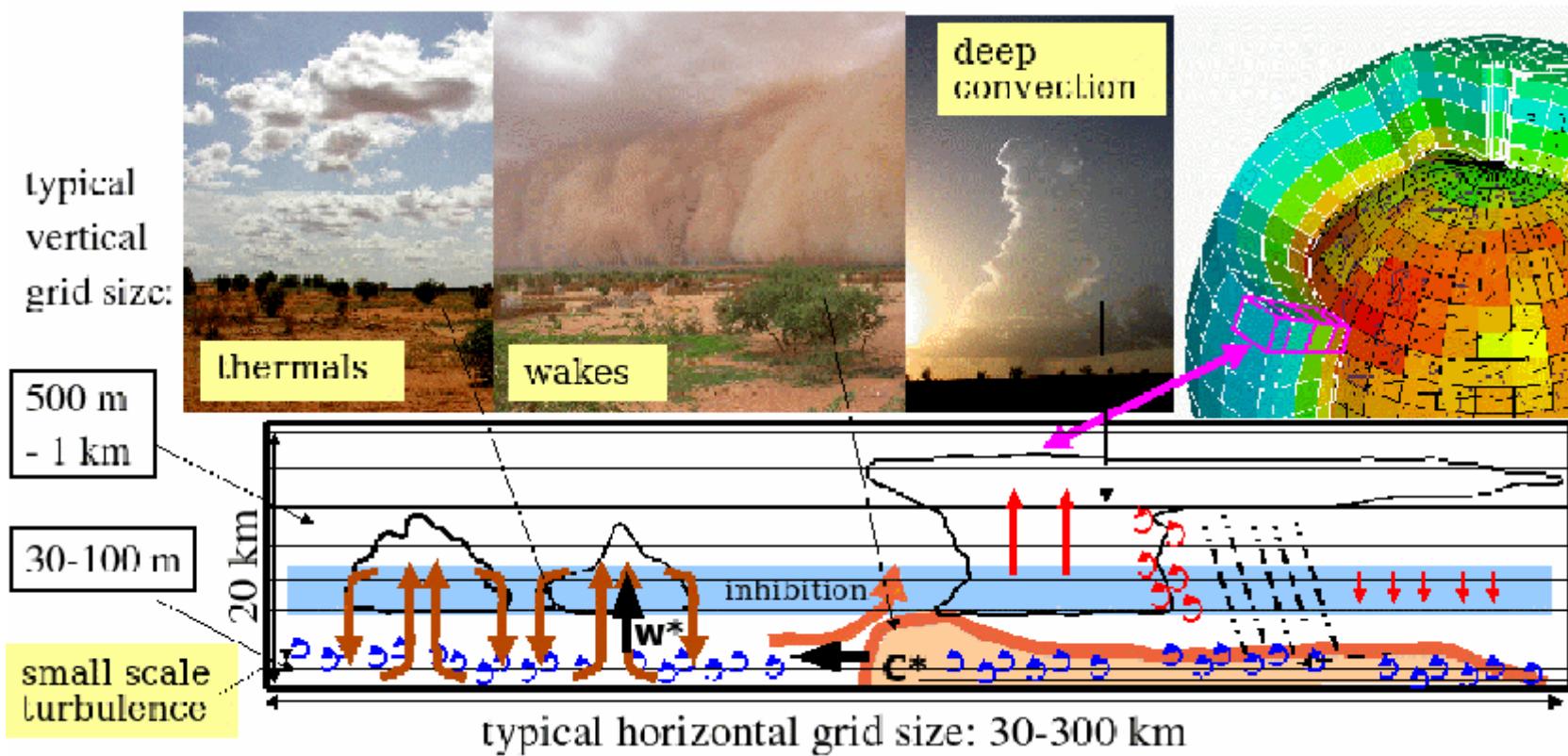
*It is possible to improve the reliability of climate models
by improving their physical content*

- Taking into account **coherent structures of the convective boundary layer** improves the representation of the diurnal cycle of the boundary layer and cumulus clouds
- Taking into account **cold pools generated by precipitation evaporation** improves the representation of deep convection development
- Controlling **deep convection triggering by energy provided by thermals and cold pools** improves the representation of the diurnal cycle of deep convection in a mid-latitude case, but not in a semi-arid environment:

**What key processes are still missing?
Help of observational and LES communities needed!**

- **ARM observations** essential to develop realistic case studies for parameterization development
- A need of data to **evaluate the internal parameters of parameterizations:** updrafts/downdrafts speed, size, mixing rates, statistical characteristics of structures

The diurnal cycle of deep convection over land



Diurnal cycle of deep convection on 27 June 1997 in Oklahoma (EUROCS case)

